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A Study of Permissioned Blockchain-Based Framework for Land Ownership Tracking in Indonesia

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Abstract
The rapid development of the economy in Indonesia has made land an important asset. The land registry system in Indonesia or known as Pendaftaran Tanah Sistematik Lengkap (PTSL) is enforced by the government to govern land property ownership management. However, the current land registry uses a conventional information system which lacks the ability to track data changes and verify their integrity, especially in land ownership documents. Introduction of unintended or fraudulent changes to the data may be made to look natural. This could be identified from the possibility of unauthorized users tampering and modifying the data in the land ownership document. Usually, they modify the data in land ownership documents mainly for their own personal gains or some might even attempt to monopolize the land transactions market or conduct illegal acts such as corruption. This prolonged issue could further lead to land disputes and uncertainty in land ownership issues. Therefore, this paper aims to propose a proof-of-authority permissioned blockchain concept to digitize and track land ownership registration. By utilizing blockchain technology, all of the records will be validated and stored securely in the blockchain network. In addition, permissioned access is added to only allow authorized users able to access the system; thus only specific users are able to perform actions on the system and are required to identify themselves. Through this proposed solution, the integrity of changes** *in* **land ownership documents can be achieved and validated.
Keywords: ***land registry, blockchain, proof of authority, land certificate management, Indonesia***

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I. INTRODUCTION

For legal certainty and the protection of land rights, land tracking is necessary. Monitoring the land tracking helps identify the status of a land plot, who owns it, what rights it has, how large it is, and what it is used for, and other information in addition to protecting the owner [1]. The assurance of legal certainty to be fulfilled in this land tracking involves the certainty of the status of the registered rights as well as the subject and object of the rights. As evidence and recognition of the rights, land registration produces a certificate [2] which can be used for tracking information about certain land. The government performs land recognition through the National Land Agency or *Badan Pertanahan Nasional* (BPN). The Head of BPN is held by the Minister of Agrarian Affairs and Spatial Planning or *Menteri Agraria dan Tata Ruang*/*Badan Pertanahan Nasional* (hereinafter referred to as the Ministry of ATR/BPN). The Ministry of ATR/BPN has the task of carrying out land registration throughout the territory of the Republic of Indonesia and as the agency that issues land rights certificates [4].

Furthermore, even though the ownership land record has been so structured and organized, invalid land rights and certificates still can be found. This happens due to current document may seem has lack of transparency [13], proven by there are many cases of overlapping land and duplicated land certificates which in result there are frequent confrontations between public stakeholders and people, and these two groups never come together to generate synergy between their respective interests [6]. Following to the report of the Ministry of ATR/BPN Directorate of General for Handling Agrarian Problems, Space and Land Utilization, there have been 116 applications followed up by the Ministry of ATR/BPN out of 645 requests for cancellation of land rights/certificates of land rights since 2018-2019 [5]. This indicates that there is the need for a system that can track the land ownership so that all the possible information may be recorded in order to reduce those problems.

Forgery of land certificates can be found in land sale and purchase transactions. In this transaction, it is necessary to attach a certificate of land sold. The certificate owned by this seller needs to be verified to avoid forgery. This inspection can only be carried out by an official certifier of title deed or Pejabat Pembuat Akta Tanah (PPAT). PPAT is an official who makes a deed of sale and purchase intended for a change in land ownership. This can lead to manipulation between the seller and the notary in providing the results of the authenticity of the land certificate so that the transaction continues. Thus, when the buyer submits a change of ownership application, BPN can reject this application because the previous certificate was not valid.

Because of its potential applications in a variety of domains, blockchain is now an interesting topic of discussion as well as a trend that is surprising people all over the globe. The Blockchain idea, which was first solely applied to the realm of Bitcoin, has produced a paradigm change, and this is something that cannot be denied as society progresses. Because of this, it is necessary to explore the possibility of redeveloping the idea in order to adapt it for usage in a variety of different industries, one of which is archiving. Consequently, blockchain technology has recently emerged as an important subject of discussion among archivists in various countries [9].

Therefore, this is one form of initiation that is an attempt to take on a role as a major player in the use of Blockchain technology and gain extraordinary efficiency in a variety of fields, one of which is in the land sector considering the emergency situation involving land disputes in Indonesia. With the overall transition to digital or paperless, the use of Blockchain for tracking land ownership is considered as a form of initiation.

There are several existence researches related to the implementation of blockchain in land registry problems. In the study [10], it proposed a blockchain-based framework for land registry in Malaysia. The major issues identified in the land registry problem in Malaysia is due to the increasing fraudulent cases as the current land registry system has a lot of vulnerabilities which can be exploited by the attacker. As a solution, the study proposed a system "ChainMyLand" which allows users to register their land, perform buying and selling transactions, view land status, and view reports of the land owned. This framework is secured using blockchain technology, utilizes a "MetaMask" online wallet to support payment transactions, and works within the Etherum environment. However, due to lack of information associated with the potential risks when implementing the blockchain framework; there is a need for an adaptive policy document to support industry environment and to identify associated risks when implementing the blockchain framework into the current system.

Another study [11], proposed a proof-of-concept blockchain-based framework for land registration problems in Pakistan. A significant and authenticated conceptual framework is offered where it ensures transparency, security, and accountability can be achieved without a third party. The framework is using a private and permissioned based blockchain; as it is designed only some entities will interact with the system and to keep track on who can interact with the ledger. Validation through proof-of-concept results in an idea that the system can also be built for management of land registry record systems. Nonetheless, the system still uses private blockchain; it could be further extended to the public to connect directly

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with the system and more people can gain the information about the land asset.

On the other hand, a study [12] proposed a framework using hybrid decentralized blockchain and various consensus algorithms to validate the transactions in land and property ownership. In addition, the approach aims to handle all the aspects of property ownership such as partition of land, hereditary cases, and disputed land segments. The system is implemented in the Ethereum environment which leads it to have lower transaction processing time. However, as the cost of transaction in Ethereum will keep increasing and has higher rates as compared to the traditional system, there is always an uncertainty presented about the required cost in each of the transactions.

II. LAND USE RIGHTS

Land ownership status in Indonesia is issued by the Badan Pertanahan Nasional (BPN) in the form of a certificate. This certificate is written evidence that gets legal recognition. According to Law Number 5 Year 1960 concerning Basic Regulations on Agrarian Principles (UUPA), the types of land ownership status are as follows.

a. *Hak Milik* (Right of Ownership)
b. *Hak Guna Bangunan* (Right of Building)
c. *Hak Guna Usaha* (Right to Cultivate)
d. *Hak Pakai* (Right to Use)
e. *Hak Sewa* (Lease)
f. *Hak Memungut Hasil Hutan* (Right to Manage Forest Harvesting)
g. *Hak-Hak yang Bersifat Sementara* (Temporary rights), such as *Hak Gadai, Hak Usaha Bagi Hasil, Hak Menumpang dan Hak Sewa Tanah Pertanian* (Liens, Profit Sharing Business Rights, Right of Lodging and Agricultural Land Lease Rights)

In the current system, there are 6 stages for land registration, as shown in Fig. 1:

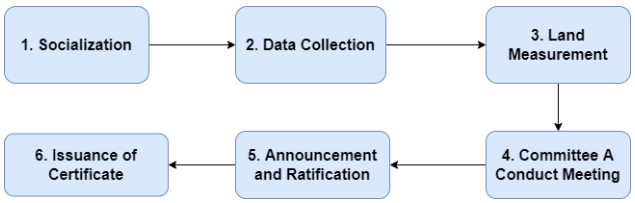

Fig. 1. Land Registry Flow in Current System

1. Socialization
   In this initial stage, there will be a socialization conducted by BPN *(Badan Pertanahan Nasional)* officers in the residential or rural area. Followed by all of the PTSL participants according to the socialization schedule.

2. Data Collection
   Officers will ask a series of questions such as the history records of the land ownership, who owns the land currently, the basis of land ownership (whether it is from inheritance, grant, sell or purchase), and taxes (BPHTB *(Bea Perolehan Hak atas Tanah dan Bangunan)* / PPh *(Pajak Penghasilan)*).

3. Land Measurement
   Surveyor will measure the location of the land, area, size, and boundaries of the land.

4. Committee A Conduct Meeting
   The committee consists of 3 people from BPN *(Badan Pertanahan Nasional)* and one representative from the village conducts a trial. This trial aims to identify and research on the current juridical data, assess the land measurement result, collect inputs or conclusions from the respective parties involved, and ask for additional information.

5. Announcement and Ratification
   The announcement period is 14 days and will be posted at the village office or land agency office. The announcement consists of a list of approved land registry issuance; including information such as owners' name, location of land, area and size of land owned.

6. Issuance of Certificate
   In the final stage, the ATR *(Agraria dan Tata Ruang)*/BPN will issue and distribute the land certificate to the participants/owner.

After that, if a land sale and purchase transaction occurs, the ownership status of the certificate needs to be updated. The following describes the flow of altering land ownership status, as shown in Fig 2:

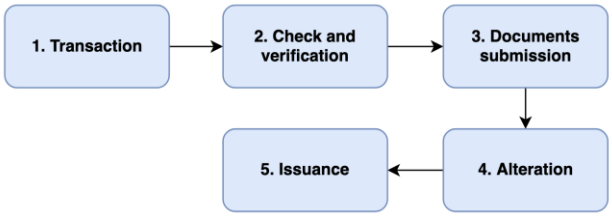

Fig. 2. Alteration Flow of Land Ownership Status

1. Transaction: Sale and purchase transactions facilitated by PPAT
   The process of land purchasing and selling transactions needs to be conducted through PPAT. According to the government regulation (*Peraturan Permerintah Nomor 37 Tahun 1998 Pasal 1 angka 1)*, it is stated that PPAT is the legal

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staff that has the authority to issue land ownership certificates based on the law and regulations that are regulated. The land ownership certificate is concrete evidence of buying and selling land transactions and serves as one of the requirements to request an alteration in land ownership status.

2. Check and verification: Checking and verifying traded land certificates by PPAT
   Before any land purchasing or selling transaction occurs, PPAT will check and validate the authenticity of the land certificate that will be used in the transaction. If the authenticity of the land certificate can be validated, then will proceed to the purchasing and selling transaction.

3. Documents submission: PPAT provides supporting documents for the land ownership status alteration to BPN
   After the land transaction process has been successfully executed, PPAT will hand over all of the administrative documents to the BPN for further process into the alteration of land ownership status stage.

4. Alteration: BPN alters the land ownership status
   BPN will record all of the changes happening in the land ownership status, along with the owner's details and land details will be recorded into a land document or usually known as *Buku Tanah.*

5. Issuance: BPN issues new certificate with the updated ownership status
   After BPN has finished recording the details, BPN will issue a new land ownership certificate with the latest updated ownership status.

III. BLOCKCHAIN AND LAND OWNERSHIP REGISTRY

A blockchain stores the data in the form of blocks. Each block stores various data depending on the type of the blockchain. The hash value of each block acts as a unique identifier in the chain. A block is linked to a previous block by including its hash. Blockchain requires all of the consecutive blocks to have the correct and exact hash value from the previous block in order to be valid.

When changing the data in one of the blocks, it will generate a new hash value. However, the succeeding block will become invalid, as it doesn't have the correct hash value from the previous block. This property allows anyone to validate the integrity of the chain such that no alteration happens in any part of the chain. Furthermore, there is a merkle tree involved in the blockchain structure; where this merkle tree is also known as binary hash tree which aims to take all of the data and create a hash to generate the merkle root. The merkle root is generated through hashing all of the transactions hashes together in pairs to create a unique hash for the transaction in the blocks. For example, as shown in Fig. 2, the combination of hashing pairs between Hash 1_2 and Hash 3_4 will generate the merkle root.

In addition, since blockchain is a decentralized and collaborative effort, anyone participating in a blockchain network will have a partial or complete copy of the chain. This allows the chain to exist in multiple places. Any attempt to tamper the chain in one place would render it useless in another. Thus, it is ensured to discourage attacks on the chain since anyone who wishes to tamper with the chain must control a majority of the blockchain system as a whole.

The blockchain proposed in this paper follows a general blockchain model. The transactions performed on the blockchain are changes used to track issuance, transfer, or revocation of land ownership. Fig. 3 shows the block structure in the blockchain structure.

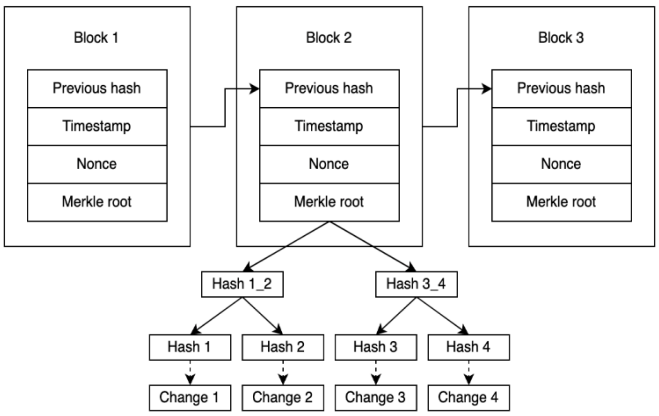

Fig. 3. Block Transaction and Hash Structure Diagram

We define a block in the land registration chain as containing a list of changes. Each change in the block pertains to a transition from a previous state to a new state. A change takes one or more input states and produces one or two output states. A state that has been consumed by a change is declared invalid; the state will no longer be valid and can't be used for further transactions in the blockchain.

For instance, Alice owns a piece of land. Alice sells this piece of land to Bob and now Bob has become the owner of the land. However, due to how transactions work in the blockchain, it is impossible for Alice to sell the land to another person; since the ownership has already been transferred to Bob. Furthermore, this kind of transaction will be invalid, as the state has already been consumed in the previous land transaction from Alice to Bob.

Fig. 4 shows the illustration of a change. It is the transaction model in our blockchain. It represents the transition happening between input and output states in the blockchain network. The input and output states generally refer to ownership entitlements. Input states refer to the initial state of the land status, while output states refer to the final result of the state after a transaction has happened. Thus, every change will destroy the existing entitlements

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and generate new ones. This mechanism removes the possibility of "double spending", i.e. overlapping land ownership.

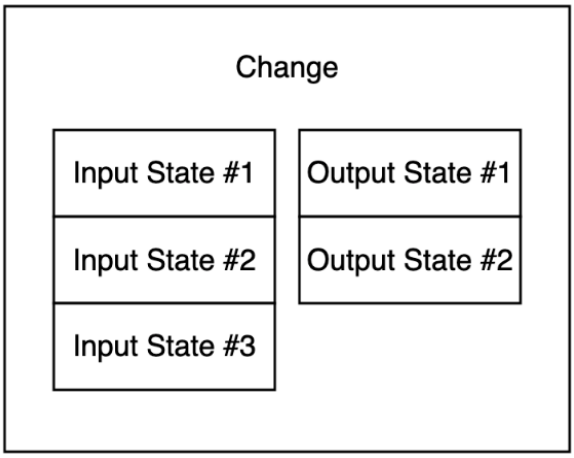

Fig. 4. Changes in Blockchain States

The transaction model can be formally defined as the function:

$$Apply(S,T) \rightarrow S' \mid Error \quad (1)$$

where S is the collection of initial states, T is a change, and S' is the resulting collection of states. S and S' correspond to input states and output states respectively. An error occurs when a change is illegal; violating the defined properties of changes.

For instance, Alice who owns an entitlement A wishes to transfer it to Bob. The change T would therefore take entitlement A as the input state and produce a new entitlement A' owned by Bob. Alice's entitlement can no longer be used in any subsequent changes. This transaction is shown in Fig. 5.

$$Apply(\{Alice: [A], Bob: []\}, "transfer\ entitlement\ A\ from\ Alice\ to\ Bob") \rightarrow \{Alice: [], Bob: [A']\} \quad (2)$$

where:

$$A = \{Owner: "Alice", Plot: [[0.0,0.0], [1.0,0.0], [1.0,1.0], [0.0,1.0]]\}$$
$$A' = \{Owner: "Bob", Plot: [[0.0,0.0], [1.0,0.0], [1.0,1.0], [0.0,1.0]]\}$$

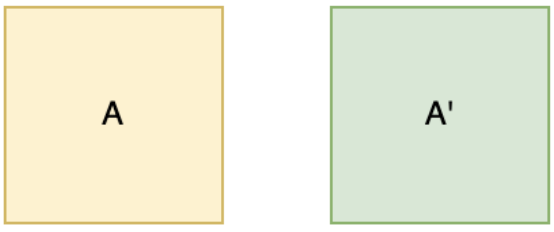

Fig. 5. Illustration of Transfer Entitlement from Alice to Bob

In the case where Alice wishes to transfer only a portion of the entitlement, the change T would produce two new entitlements A' and B'. This transaction is illustrated in Fig. 6.

$$Apply(\{Alice: [A], Bob: []\}, "transfer\ part\ of\ entitlement\ A\ from\ Alice\ to\ Bob") \rightarrow \{Alice: [A'], Bob: [B']\} \quad (3)$$

where:

$$A = \{Owner: "Alice", Plot: [[0.0,0.0], [1.0,0.0], [1.0,1.0], [0.0,1.0]]\}$$
$$A' = \{Owner: "Alice", Plot: [[0.0,0.0], [0.5,0.0], [0.5,1.0], [0.0,1.0]]\}$$
$$B' = \{Owner: "Bob", Plot: [[0.5,0.0], [1.0,0.0], [1.0,1.0], [0.5,1.0]]\}$$

Fig. 6. Illustration of Transfer Portion of Entitlement from Alice to Bob

In the case where Alice receives an entitlement B and Alice wishes to join it with the existing entitlement A, the change T would take both A and B, producing only one new entitlement A. This transaction is illustrated in Fig. 7.

$$Apply(\{Alice: [A], Bob: [A]\}, "transfer\ entitlement\ B\ from\ Bob\ to\ Alice\ and\ join\ it\ with\ entitlement\ A") \rightarrow \{Alice: [A], Bob: []\} \quad (4)$$

where:

$$A = \{Owner: "Alice", Plot: [[0.0,0.0], [0.5,0.0], [0.5,1.0], [0.0,1.0]]\}$$
$$B = \{Owner: "Bob", Plot: [[0.5,0.0], [1.0,0.0], [1.0,1.0], [0.5,1.0]]\}$$
$$A' = \{Owner: "Alice", Plot: [[0.0,0.0], [1.0,0.0], [1.0,1.0], [0.0,1.0]]\}$$

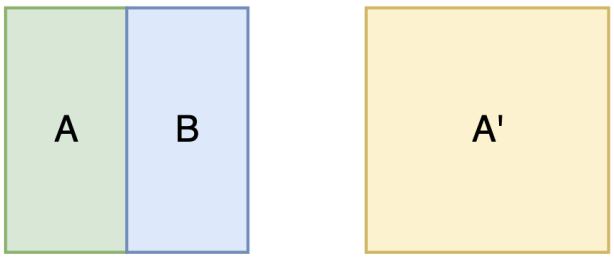

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Fig. 7. Illustration of Transfer Portion of Entitlement from Alice to Bob

However, due to this transition model, a specific mechanism must be assumed for issuance of new unclaimed ownership and revocation of existing ownership. A super state XX would be created as the initial change in the chain. The issuance change T_0T_0 would then takes initial states SS and produces $S'S'$, both of which includes XX such that XX is constant throughout the chain.

$$Apply(\{X: [X]\}, "create\ super\ state") \rightarrow \{X: [X]\} \quad (4)$$

Thus, if Alice buys an unclaimed piece of land, a new entitlement A will be produced from the super state X.

$$Apply(\{Alice: [], X: [X]\}, "create\ entitlement\ A\ and\ give\ it\ to\ Alice") \rightarrow \{Alice: [A], X: [X]\} \quad (5)$$

where:

$$A = \{Owner: "Alice", Plot: [[0.0,0.0], [1.0,0.0], [1.0,1.0], [0.0,1.0]]\}$$
$$X = \{Owner: "Sudo", Plot: [[-\infty, -\infty], [\infty, -\infty], [\infty, \infty], [-\infty, \infty]]\}$$

Additionally, when Bob surrenders an entitlement A, the function takes A and X. Entitlement A will be destroyed, producing the super state X.

$$Apply(\{Bob: [A], X: [X]\}, "destroy\ entitlement\ A") \rightarrow \{Bob: [], X: [X]\} \quad (6)$$

where:

$$A = \{Owner: "Bob", Plot: [[0.0,0.0], [1.0,0.0], [1.0,1.0], [0.0,1.0]]\}$$
$$X = \{Owner: "Sudo", Plot: [[-\infty, -\infty], [\infty, -\infty], [\infty, \infty], [-\infty, \infty]]\}$$

This approach provides a mechanism for land ownership entitlement issuance, transfer, and revocation.

IV. NETWORK AND PARTICIPANTS

We propose the use of a permissioned blockchain network which is operated using the proof-of-authority mechanism. This is chosen to control and limit access while providing data integrity and trust. As such, a public key infrastructure (PKI) will be established at the national level. The national land authority will act as the certificate authority (CA) of the network and control the issuance and revocation of all certificates. Consequently, any interaction with the network will require a valid certificate with authorization for the designated purposes. This allows participants in the network to ensure that any given operation is legitimate. Additionally, all certificates must be issued for the strictest purpose possible to reduce the impact of possible attacks on the network and the blockchain.

In Fig. 8, it shows the illustration of the proposed blockchain diagram business flow. It consists of the individual involved in the transaction (Alice and Bob), the land authority, and the blockchain. In this scenario, Alice sells a plot of land to Bob and then Bob registers the new ownership under his name to the land authority. The land authority verifies the ownership claim and registers the data on the blockchain.

Fig. 8. Illustration of Proposed Blockchain Diagram Business Flow

The blockchain network and ledger will act as the mediator between local land authorities and the national land authority, as shown in Fig. 9. When an individual registers a land ownership, whether new or transferred, to their local land authority, such change will be requested to the national authority through the network. The confirmation of the request will be recorded in the blockchain ledger which the local land authority can query. Accordingly, we identify that there will be three types of participants in the network: proposer, publisher, and observer.

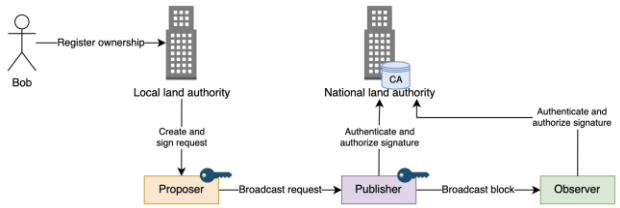

Fig. 9. Illustration of Proposed Blockchain Network Diagram in Land Registry

A proposer initiates a change request. It broadcasts individual change requests to publishers in the network. In order to limit the capability, each proposer must only be allowed to propose changes within a certain geographical area and such authorization must not overlap. Such a requirement should eliminate the possibility of duplicate ownership being issued by different local authorities. Additionally, it also limits the attack surface of the network by reducing the capabilities of proposers. This is achieved by leveraging the PKI. Therefore, this role will be fulfilled by local land authorities since they should be the only one authorized to make any land ownership changes in their designated regions.

A publisher listens for change requests for validation and eventual addition to the blockchain. It checks the request content for any errors, i.e. input states must exist and have not been spent in prior changes/blocks, and checks whether the issuing proposer is authorized to create the request. Additional human verification might also be performed. If any of the checks failed, the request would be dropped. Validated requests are collected into a block. The block is then signed and published to the network as the

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next block in the blockchain. This makes publishers the most crucial participant of the network. As such, all publishers should only be operated by the national land authority.

An observer observes the network for new blocks. It performs additional verification on arriving blocks and their changes before appending the block to its chain. It provides redundancy and preserves the integrity of the network. Proposers and publishers also act as observers. Third party organizations and institutions may be invited to become an observer to provide desired transparency and integrity in the land certificate issuance process. However, the national land authority should remain the only source of truth.

V. INFORMATION SYSTEM INTEGRATION

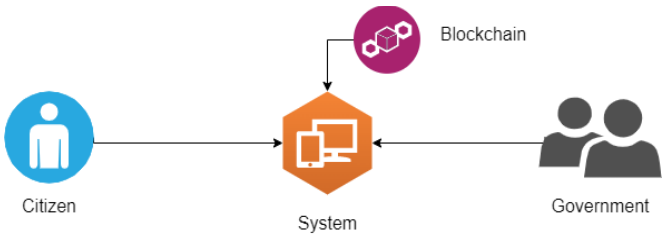

Fig. 10. Illustration of Proposed Blockchain Network Diagram in Land Ownership Tracking

An integrated web-based system and/or mobile application may interface with the permissioned blockchain in order to service land registry queries for both citizens and government. In Fig. 10, it shows the components involved in the proposed framework design; which consist of citizen, system, blockchain, and government.

To ease the citizens and to provide a more user- friendly approach, citizens will use a mobile application to perform request and land ownership tracking. This application will provide features for the citizens to enable them to monitor and track their land ownership status whether it has already been processed by the government or not. From the government side, they can monitor the land registry requests by the citizens in the web-based system, processing the administrative documents, and monitoring or tracking any changes in land ownership status.

Through this proposed system, accountability and transparency can be achieved. As all of the land records are integrated and stored into the blockchain system, all of the authorized users are able to monitor and see the current status of the records. This can solve the issue happening in the manual current existing system; where due to many parties involved, it is likely to have potential fraud documents submitted during the land transaction process.

In addition, the objective to integrate this system with blockchain; is to achieve and maintain the integrity of the records. As has been discussed in the previous section, most land disputes issues happened in Indonesia due to government policies or duplicated land certificates for a particular land. This issue happens due to lack of consistency and integrity of the records stored using the manual current system. Hence, the proposed system aims to highlight through using blockchain to ensure the integrity of the data; as all of the existing transactions such as land ownership status will be recorded in the system.

VI. DISCUSSION

The use of blockchain provides accessibility and transparency into the land registry processes and information. Records of land ownership changes will be immutable throughout the blockchain. Additionally, each record is signed by the respective party that assumes responsibility for the change. This prevents any unauthorized or otherwise fraudulent changes to be made without violating the integrity of the blockchain.

The blockchain also shows the history of any given land plot. It tracks changes from the initial ownership claim to subsequent transfers. This provides a tool for the government or other land administration apparatus to verify current or past ownership. Additionally, the blockchain acts as a coordination mesh between various local and national authorities such that no changes conflicting with the current view of the blockchain state can be introduced into the system. This helps prevent common problems such as duplicate issuance of land ownership certificates.

VII. CONCLUSION

In conclusion, this research has identified and studied the problems that occur in tracking land ownership in Indonesia. The lack of transparency of ownership and the lack of digitization for the transfer of land ownership in the current system are the main factors causing land disputes. A conceptual flow of how blockchain can solve the problem of tracking land ownership has been provided in this study. In addition, the proposed blockchain and network model has been included in this study to provide initial concepts and solutions to overcome the problem of tracking land ownership that occurs in Indonesia.

As a future work, this study can be further extended to the scope of tracking different ownership or use right status. We may want to track the issuance and revocation of time-limited use rights such as *HGB (Hak Guna Bangunan)*. This could be another research opportunity to explore, since the use of blockchain should be able to address the potential risks and adapt to the flow in relation to changes in ownership and land status. Furthermore, tracking the status of lands that are being rented or leased, could also be another idea to research. Since, there will be other government policies and regulations involved for that process.

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